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PHYSICO-CHEMICAL PROPERTIES OF FUELS: AN OVERVIEW

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ABSTRACT

High viscosity causes poor atomization of the fuel in the combustion chamber and affects the peak injection pressure, the injection duration, the injection pressure-time history, the spray cone angle, and the quality of atomization. Transesterification may be either an acidolysis, where the acid component of an ester is replaced by another acid, or an alcoholysis, where the alcohol component of an ester is replaced with a different alcohol. Vegetable oils are esters of fatty acids and glycerol. In this work, the transesterification being studied is an alcoholysis where the glycerine component of a vegetable oil is replaced by an alcohol. Transesterification is a way to lower the viscosity of the vegetable oil by breaking up the triglyceride molecule and separating the fatty acid molecules from the glycerin molecule. In this paper, fuel related properties of the test fuels in consideration have been studied.

Keywords: *Atomization, Combustion Chamber, Spray Cone Angle, Transesterification, Acidolysis.*

Introduction

The karanj (also called Pongam in Southern India) oil is bitter, red brown, thick, nondrying and inedible. The physical and chemical properties, of vegetable oil are important for combustion and storage as fuel. A comparison of the physico-chemical properties of karanj oil and diesel is given in Table 1.

Table 1: Comparison of Physico-Chemical Properties of Karanj Oil and Diesel

S. No.	Parameters	Karanj Oil	Diesel
1	Saponification Value	185 - 195	0
2	Iodine value	80 - 90	38.30
3	Acid Value (Max.)	20	0.06
4	Moisture (% max.)	0.25	24.66
5	Color in 1/4 inch cell (Y+5R)	40	102.5
6	Refractive Index (40° C)	1.473 -1.479	1.472
7	Specific Gravity (30° C)	0.90 - 0.94	0.82 - 0.86
8	Cloud Point (°C)	15	13
9	Pour Point (°C)	-2 to -5	1

- **Iodine Value**: The iodine value of a substance is a measure of the degree of chemical instauration in a chemicals olefinic bond. Iodine values are used to determine the oxidative stability of a fuel in order to determine storage stability. Higher iodine value indicates more unsaturated bonds, which equate to less storage stability. Thus, iodine number refers to the amount of iodine required to convert unsaturated oil into saturated oil. The iodine value of karanj oil is 82.78. Duffield has suggested that iodine value greater than 115 are unacceptable.
- **Calorific Value**: The calorific value of a fuel is a measure of the amount energy (calories) that the fuel contains per unit mass. The calorific value of karanj oil is 37-38 MJ/kg as compared to 40-47 MJ/kg that of diesel.

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- **Density**: The density of a fuel is a measure of its weight per volume. The density of the fuel is important because many diesel engine fuel injection pumps use the weight of the fuel for measurement and dispensing. A denser fuel would therefore be dispensed in a lower volume. The density of karanj oil is 0.91 kg/m^3, and that of diesel is 0.82-0.86 kg/m^3 at 15° C.
- **Viscosity**: It is the measure of the thickness of a fluid. Viscosity is an important measure of a fuel because the atomization characteristics of the fuel are affected by it. Moreover, it is important for the flow of oil through pipelines, injector nozzles and orifices. Viscosity of fluids varies inversely to temperature. Karanj oil has a viscosity of 74.14 St at 30° C, 44.80 St at 40° C and 8.59 St at 100° C while that of diesel is 8.54 St at 30° C.
- **Cetane Number**: It is the measure of ignition quality of diesel fuels. This is the amount of time it takes for the fuel air mixture to ignite, once it is injected into the combustion chamber. Higher cetane number has shorter ignition delay. The cetane number of diesel is 48.
- **Cloud Point**: Cloud Point is the temperature at which the fluid develops ice crystals and begins to clog small openings, such as fuel filters. This measure becomes important in cold climates. The cloud point of Karanj oil is 15° C and of diesel fuel is 13° C.
- **Pour Point**: Pour point is the lowest temperature at which a fluid will flow. This measure is relevant in cold places. The pour point of karanj oil is -2 °C to -5° C while that of diesel is around 1° C max.
- **Flash Point**: Flash point of a fuel is defined as the temperature at which it will ignite when exposed to a flame or spark. The flash point of karanj oil at 230° C is much higher than that of diesel, which is 66° C. While this higher flashpoint of karanj oil does not affect its combustion in CI engine, this makes it easier to handle and store.

Chemical Composition

Karanj oil is reported to contain alkaloids demethoxykanugin, gamatay, glabrin, glabrosaponin, kaempferol, kanjone, kanugin, karangin, neoglabrin, pinnatin, pongamol, pongapin, quercitin, saponin, β-sitosterol, and tannin. Air-dry kernels have 19% moisture, 27.5% fatty oil, 17.4% protein, 6.6% starch, 7.3% crude fiber, and 2.4% ash.

Destructive distillation of wood yields, on a dry basis: charcoal 31%, pyroligneous acid 36.69%, acid 4.3%, ester 3.4%, acetone 1.9%, methanol 1.1%, tar 9%, pitch and losses 4.4% and gas 0.12 cu m/kg. Manurial values of leaves and twigs are respectively: nitrogen 1.16, 0.71; phosphorous (P_2O_5) 0.14, 0.11; potash (K_2O) 0.49, 0.62; and lime (CaO) 1.54, 1.58%. Fatty acid composition of karanj oil is given in Table 2.

Table 2: Fatty Acid Composition of Karanj Oil

S. No.	Fatty Acid	Structure	Formula	Weight (%)
1	Palmitic	16:0	$C_{16}H_{32}O_2$	3.7 - 7.9
2	Stearic	18:0	$C_{18}H_{36}O_2$	2.4 - 8.9
3	Oleic	18:1	$C_{18}H_{34}O_2$	44.5 - 71.3
4	Linoleic	18:2	$C_{18}H_{32}O_2$	10.8 - 18.3
5	Lignoceric	24:0	$C_{24}H_{48}O_2$	1.1 - 3.5
6	Arachidic	20:0	$C_{20}H_{40}O_2$	2.2 - 4.7
7	Behenic	22:0	$C_{22}H_{44}O_2$	4.2 - 5.3
8	Eicosenoic	20:1	$C_{20}H_{38}O_2$	9.5 - 12.4

- **By-Products**: The oil extraction process produces oil cakes not suitable as animal feed. It has high protein (31.9%) and low fiber content (3.7%).

Methyl Esters of Vegetable Oils

Fuel related physical properties of methyl esters of some vegetable oils are presented in Table 3.

Gaseous Fuels

Some relevant properties of gaseous fuels that can be utilized in IC engines are presented in Table 4.

Table 3: Properties of Methyl Esters of Some Vegetable Oils

S. No.	Vegetable oil methyl ester	Cetane Number	Calorific Value (MJ/kg)	Viscosity (mm^2/s)	Cloud Point (°C)	Pour Point (°C)	Flash Point (°C)
1.	Cottonseed	51.2	--	6.8 (21 °C)	--	-4	110
2.	Rapeseed	54.4	40.44	6.7 (40 °C)	-2	-9	84
3.	Safflower	49.8	40.06	--	--	-6	180
4.	Soybean	46.2	39.80	4.08 (40°C)	2	-1	171
5.	Sunflower	46.6	39.80	4.22 (40 °C)	0	-4	183
6.	Jatropha	50	38.45	5.65 (40 °C)	--		170
7.	Castor	--	31.94	--	-5	-9	60
8.	Karanj	--	36.12	9.60 (40 °C)	--	--	187
9.	Peanut	54	33.6	4.9 (37.8 °C)	5	--	176
10.	Palm	62	33.5	5.7 (37.8 °C)	13	--	164

Table 4: Properties of Some Gaseous Fuels

Properties	Diesel	Bio-gas	LPG	Natural gas	Producer gas	H2
Composition (%)	C= 84.8 H2 =15.2 (By weight)	CH4≈ 50- 60 CO2 ≈ 30-45 H2 & N2 ≈ 5- 10 CO ≈ 0.1 H2S ≈ 0.1	C2H6 = 1 C3H8 = 62 C4H10 = 37	CH4= 95.3 C2H6=2.16 C3H8=0.19 N2 = 1.86 CO2= 0.44 n-Butane = 0.02	CO = 44 H2 = 49 N2 = 4 Rest CH4 & CO2	H2 =100
Lower heating value (kJ/kg)	42800	20900	46000	47800	12200 (kJ/m3)	121000
Density (kg/m3)	840	1.1	2.24	0.79	1.05	0.090
Flame Speed (cm/s)	2 - 8	25	38.25	34	20 - 30	265-325
Stoichiometric (A/F) kg/kg	14.6	6 Nm3 air/ Nm3 gas	15.5	17.3	0.95-1.30 Nm3 air/ Nm3 gas	34.30
Flammability limits (% vol. in air)	0.6-7.50	7.50- 14	2.15–9.60 (propane)	5.3 - 15	7 – 21.60	4 - 75
Octane Number (Research)	--	120	103 - 105	130	100 - 105	--
Auto-ignition temperature (°C)	315	700	493 – 549 (propane)	730	625	585
Latent heat of vapourisation (kJ/kg)	251	--	428 (propane)	--	--	--

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